CHAPTER 6

FIELD RIGGING AND HOISTING SYSTEMS

This chapter presents information on how to rig and erect field hoisting systems used within the Naval Construction Force (NCF).

Formulas are given on how to determine or find the safe working load (SWL) of fiber/ synthetic line and wire rope. These formulas are important when constructing a field hoisting system and also when lifting by any other means. In addition, the breaking strengths of fiber line and wire rope are covered.

FIELD-ERECTED HOISTING DEVICES

The term *FIELD-ERECTED HOISTING DEVICE* refers to a device, generally of a temporary nature, that is constructed in the field, using locally available material, for the purpose of hoisting and moving heavy loads. Basically, it consists of a block-and-tackle system arranged on some form of skeleton structure consisting of wooden poles or steel beams. The tackle system requires some form of machine power or work force to do the actual hoisting. The skeleton structure with attached tackle is held in place and supported by means of guy lines anchored to holdfasts in the ground.

HOLDFASTS

Gin poles, shear legs, and other rigging devices are held in place by means of guy lines anchored to HOLDFASTS. In fieldwork, the most desirable and economical holdfasts are natural objects, such as trees, stumps, and rocks. When natural holdfasts of sufficient strength are not available, proper anchorage can be provided through the use of man-made holdfasts. These include single-picket, combination-picket, combination-log-picket, and log deadman holdfasts.

Natural Types

When using trees or stumps as holdfasts, always attach the guys near ground level. Of course, the strength of the tree or stump is also an important factor in determining its suitability as a holdfast. With this thought in mind, NEVER use a dead tree or a rotten stump for this purpose. Such holdfasts are unsafe because they are likely to snap suddenly when a strain is placed on the guy. Make it a practice to lash the first tree or stump to a second one (fig. 6-1). This will provide added support for the guy.

Single-Picket Holdfast

Pickets used in the construction of picket holdfasts may be made of wood or steel. A wood picket should be at least 3 inches (76.2 millimeters) in diameter and 5 feet (1.5 meters) long. A SINGLE-PICKET holdfast can be provided by driving a picket 3 to 4 feet (0.9 to 1.2 meters) into the ground, slanting it at an angle of 15° opposite to the pull. In securing a single guy line to a picket, take two turns around the picket and then have part of the crew haul in on the guy as you take up the slack. When you have the guy taut, secure it with two half hitches. In undisturbed loam soil,

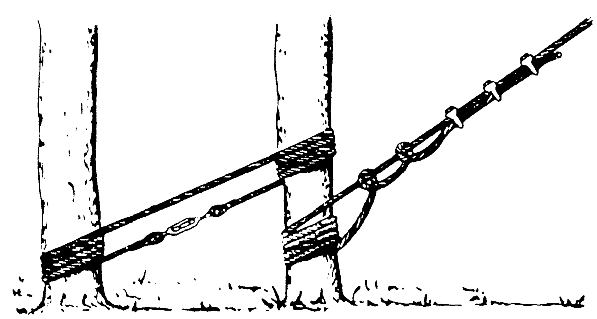


Figure 6-1.—Use of trees as natural holdfasts.

the single picket is strong enough to stand a pull of about 700 pounds (317.5 kilograms).

Combination-Picket Holdfast

A COMBINATION-PICKET holdfast consists of two or more pickets. Figure 6-2 gives you an idea of how to arrange pickets in constructing a 1-1-1 and a 3-2-1 combination-picket holdfast.

In constructing the 1-1-1 combination, drive three single pickets about 3 feet (0.9 meter) into the ground, 3 to 6 feet (0.9 to 1.8 meters) apart, and in line with the guy. For a 3-2-1 combination, drive a group of three pickets into the ground, lashing them together before you secure the guy to them. The group of two lashed pickets follows the first group, 3 to 6 feet (0.9 to 1.8 meters) apart, and is followed by a single picket. The 1-1-1 combination can stand a pull of about 1,800 pounds (810 kilograms), while the 3-2-1 combination can stand as much as 4,000 pounds (1,800 kilograms).

The combination of the pickets grouped and lashed together and the small stuff secured onto every pair of pickets makes the combination-picket holdfasts much stronger than the single-picket holdfasts.

The reason for grouping and lashing the first cluster of pickets together is to reinforce the point where the pull is the greatest. The small stuff links each picket to the next, thereby dividing the force of pull so that the first picket will not have to stand all of the strain. Using 12- to 15-thread small stuff, clove hitch it to the top of the first picket. Then, take about four to six turns around the first and second pickets, going from the bottom of the second to the top of the first picket. Repeat this with more small stuff from the second to the third picket, and so on, until the last picket has been secured. After this, pass a stake between the turns of small stuff, between EACH pair of pickets, and then make the small stuff taut by twisting it with the stake. Now, drive the stake into the ground.

If you are going to use a picket holdfast for several days, it is best to use galvanized guy wire in place of the small stuff. Rain will not affect galvanized guy wire, but it will cause small stuff to shrink. If the small stuff is already taut, it could break from overstrain. If you HAVE TO use small stuff, be sure to slack it off before leaving it overnight. You do this by pulling the stake up, untwisting the small stuff once, and then replacing the stake.

Combination-Log-Picket Holdfast

For heavy loads or in soft- or wet-earth areas, a COMBINATION-LOG-PICKET holdfast is frequently used. With this type, the guys are anchored to a log or timber supported against four or six combination-picket holdfasts. (See fig. 6-3.) The timber serves as a beam and has to be placed so that it bears evenly against the front row of the pickets. Since the holding power of this setup depends on the strength of the timber and anchor line as well as the holdfast, be sure to use a timber big enough and an anchor line strong enough to stand the pull.

Rock Holdfast

ROCK holdfasts are made by inserting pipes, crowbars, or steel pickets in holes drilled in solid

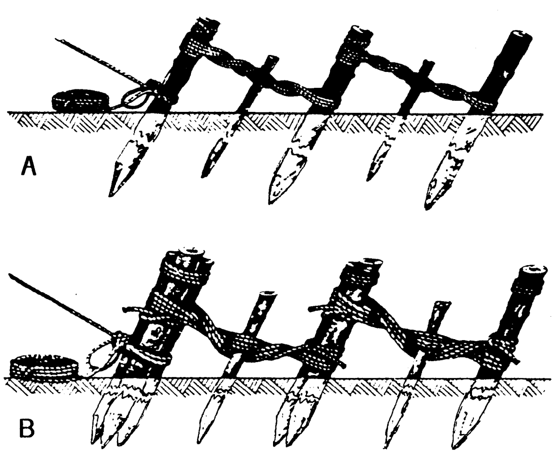


Figure 6-2.—Combination-picket holdfast: A. 1-1-1 combination, B. 3-2-1 combination.

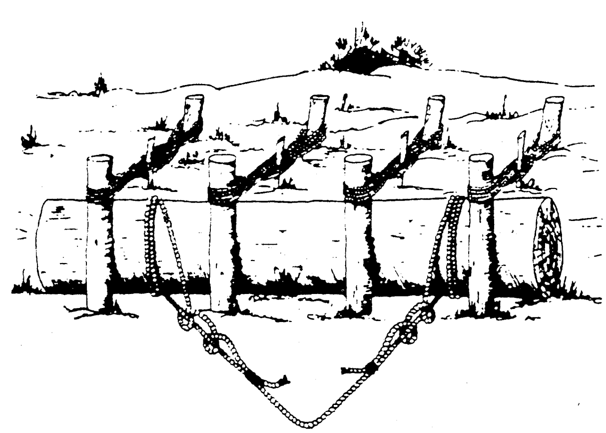


Figure 6-3.—Combination-log-picket holdfast.

rock. Using a star drill, drill holes in the rock 1 1/2 to 3 feet (75 to 90 centimeters) apart, keeping them in line with the guy. Remember to drill the holes at a slight angle so that the pickets will lean away from the direction of pull. Make the front hole about 1 1/2 to 3 feet (75 to 90 centimeters) deep and the rear hole 2 feet (60 centimeters) deep (fig. 6-4). After driving pickets into the holes, secure the guy to the front picket. Then, lash the pickets together with chain or wire rope to transmit the load.

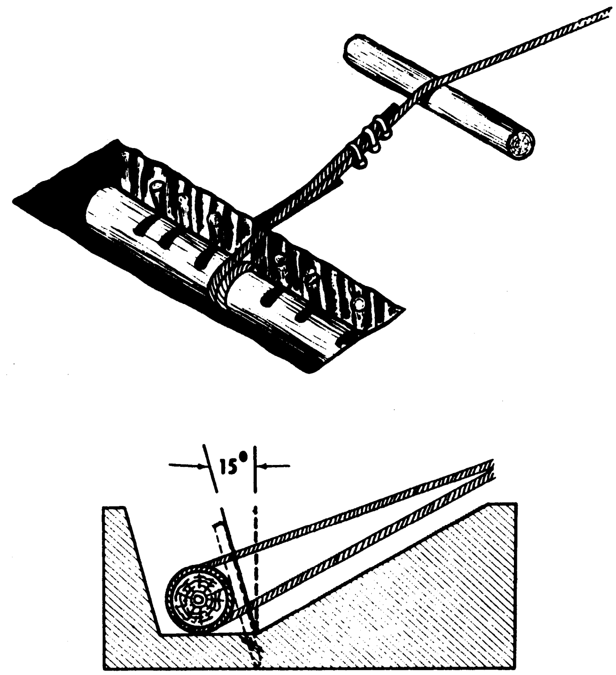


Figure 6-5.—Log deadman.

Deadman Holdfast

A DEADMAN provides the best form of anchorage for heavy loads. It consists of a log, a steel beam, a steel pipe, or a similar object buried in the ground with the guy connected to it at its center. (See fig. 6-5.) Because it is buried, the deadman is suitable for use as a permanent anchorage. When installing a permanent deadman anchorage, you should put a turnbuckle in the guy near the ground to permit slackening or tightening the guy when necessary.

In digging the hole in which to bury the deadman, make sure it is deep enough for good bearing on solid ground. The less earth you disturb in digging, the better the bearing surface will be. As shown in figure 6-5, you should undercut the bank in the direction toward the guy at an angle of about 15° from the vertical. To increase the bearing surface, drive stakes into the bank at several points over the deadman.

A narrow, inclined trench for the guy has to be cut through the bank and should lead to the center of the deadman. At the outlet of the trench, place a short beam or log on the ground under the guy (fig. 6-5). In securing the guy to the center of the deadman, see that the standing part (the part on which the pull occurs) leads from the bottom of the log deadman. Thus, if the wire rope clips slip under strain, the standing part will rotate the log in a counterclockwise direction, causing the log to dig into the trench rather than roll up and out. See that the running end of the guy is secured properly to the standing part.

Steel-Picket Holdfast

The STEEL-PICKET holdfast shown in figure 6-6 consists of steel box plates with nine holes drilled through each and a steel eye welded on the end for attaching the guy. When installing this holdfast, it is important that you drive steel pickets through the holes in such a manner that will cause them to clinch in the ground. You will find the steel-picket holdfast especially useful for anchoring horizontal lines, such as the anchor cable on a pontoon bridge. The use of two or more of the units in combination will provide a stronger anchorage than a single unit.

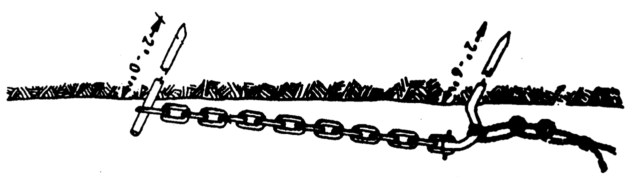


Figure 6-4.—Rock holdfast.

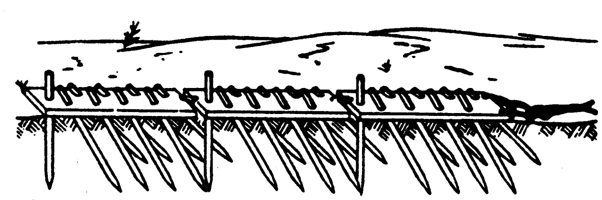


Figure 6-6.—Steel-picket holdfast.

GIN POLE

The GIN POLE is a rig constructed from a single pole, square timber, or steel beam. It stands almost vertically and is supported by guys. Loads of medium weight can be lifted from 10 to 50 feet (3 to 16 meters) by a block and tackle supported on the gin pole. The hauling part of the tackle leads through a snatch block at the base of the pole to the source of power.

The timber gin pole should not be longer than 60 times its minimum thickness because of the tendency to buckle under compression. If the pole is too short and you have to splice two together, place the sections so that the end of one touches the end of the other. This is called BUTT SPLICING. Join the sections together by bolting wooden scabs or metal plates onto them. Sometimes large spikes are used to fasten the wooden scabs. When there is a tendency on the part of a spliced pole to buckle, fasten an additional set of guys at the splice.

Guy lines, incidentally, may be either wire rope or fiber line, although wire rope is usually preferred because of its strength and resistance to corrosion and weathering. Generally, four guys are considered a minimum with 90° angles between guys. If the pole or spar supported by the guys is long and slender, it may be advisable to provide support at several points on the pole in a tiered effect.

Guy lines should be anchored a considerable distance from the base of the gin pole. The recommended minimum distance from the base of the gin pole to the anchorage of the guy line is twice the height of the pole.

The angle of the pole is especially important in the matter of stress. For instance, if the pole is vertical, the stress on each after guy is practically zero. But, when the angle between the guy and the ground is 45°, the stress on each guy is almost one half of the total load. That is why you have to use a guy that will stand stress of at least one half of the load.

The weakest point in the gin pole assembly is most likely to be the after guy. If you study figure 6-7, you will see that as the gin pole is slacked outward, distance (b) becomes less and distance (a) becomes greater. After the pole has reached a certain angle, (a) becomes greater than (b), and from then on, the guy has a strain on it greater than the weight. This increases so rapidly as the pole approaches the horizontal that the amount of strain is theoretically almost infinite when the pole is lying nearly flat. Obviously, then, the nearer the gin pole is to the vertical, the less the stress on the after guy, and the pole cannot be lowered far off the perpendicular without setting up dangerous stresses.

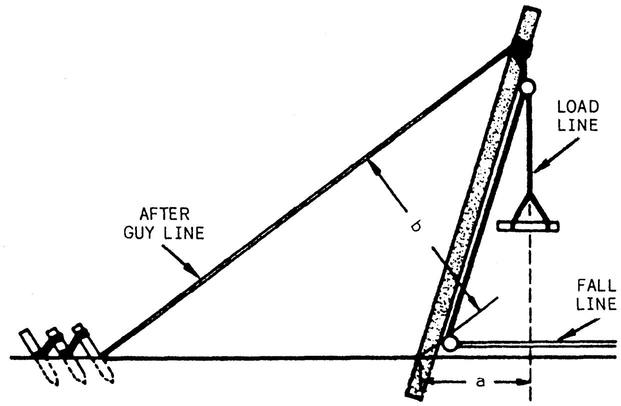


Figure 6-7.—Stress on after guy and gin pole.

The formula for finding the thrust on the pole itself is rather complicated and involves a value that is difficult to determine without the use of trigonometry. You can easily see that in the vertical position, the pole would be supporting a thrust equal to, but no greater than, the weight. As the pole is slacked outward, the thrust on it, like the stress on the guy, increases, reaching fantastic proportions when the pole gets beyond a certain angle.

About the best thing you can do, then, is to remember that a gin pole cannot be slacked to more than a few degrees off the vertical before it begins to take a heavy strain.

Rigging

The basic steps in the procedure for rigging a gin pole are given below. Learn each step listed, and study carefully figure 6-8, which shows you how a gin pole is erected and the details of the lashings.

1. Place the pole so that the base is at the spot where it is to be erected.
2. Make a tight lashing of eight or nine turns of fiber line about 1 foot (30 centimeters) from the top of the pole with two or more of the center turns engaging the hook of the upper block of the tackle. Secure the ends of the lashing with a square knot, and attach cleats to the pole flush with the lower and upper sides of the lashing to prevent the lashing from slipping.

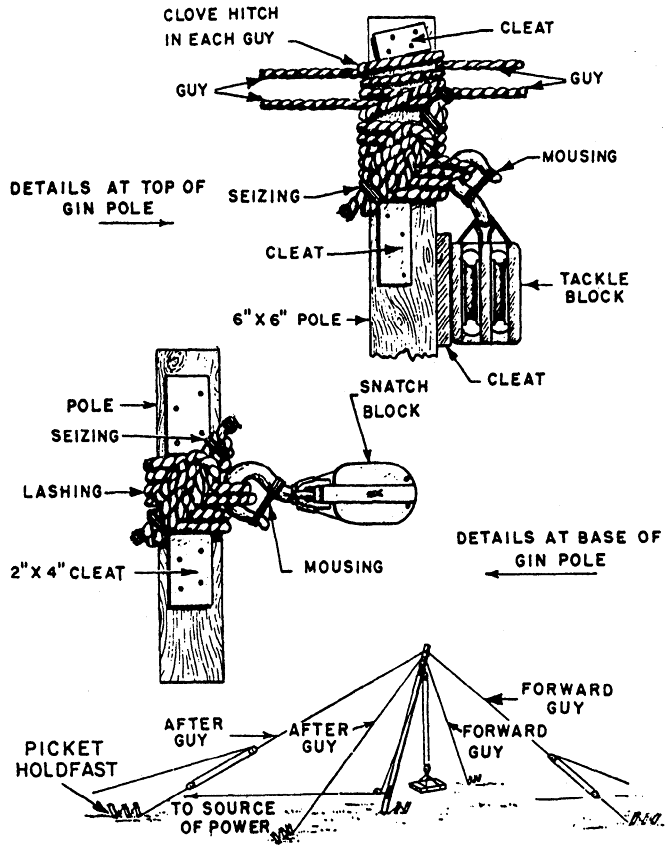


Figure 6-8.—The gin pole.

3. Lay out guy lines, each one about four times as long as the pole. Each line makes two guys if you make a clove hitch in the center and then pass it over the top of the pole above the tackle lashing. The guys lead from the pole, opposite each other, to block-and-tackle arrangements, which are attached to an anchorage. Thus, the length of the guy from the pole to the anchorage is approximately twice the length of the pole

4. Make another tight lashing (as above) about 2 or 3 feet (60 or 90 centimeters) from the base of the gin pole, and put a cleat above and below this to keep it from slipping. This is where the snatch block is secured.

5. Now, reeve your tackle so that the hauling part passes from the head block, through the snatch block, to the source of power.

6. To keep the pole from skidding while being erected and to keep it in place while a load is being hoisted, set up a picket holdfast about 3 feet (90 centimeters) from the pole base, and tie a line from the holdfast to the pole base.

7. Before erecting the gin pole, make SURE the lashings are made properly and that hooks are moused.

Erecting

Gin poles not over 50 feet (12 meters) in length may be raised easily by hand, but longer poles must be raised by supplementary rigging or power equipment. About 10 or more crew members may be needed to erect a gin pole properly, the number depending largely on the weight of the pole. Use the following procedure as a guide in erecting the pole:

1. Dig a hole for the base between 6 inches (15 centimeters) and 1 foot (30 centimeters) deep, depending on the type of soil and the weight to be lifted.

2. Lay out each guy as far as its anchorage. If tackle is NOT used on the after guys, one crew member controls the slack of each with turns around the anchorage as the pole is raised.

3. You can do one of two things to bring the movable block down within reach. You can tie a line to the hook of the movable block, or you can overhaul the tackle until it is longer than the length of the pole, and secure it to an anchorage opposite the base.

4. To raise the pole easily, start raising it by hand to about 3 or 4 feet (0.9 or 1.2 meters) from the ground. Then, round in the blocks of the after guys. While raising the pole, keep tension on the forward guys; otherwise, the pole may swing and throw all the weight to one side.

5. When the pole is upright; make all guys fast.

6. You can move the top of the pole from vertical to 15° forward without moving the base. This is called DRIFTING and should be done only while the pole is NOT loaded, unless you can regulate the tension of all guys by tackle that is secured at the end of each. You will drift the pole forward when lifting the load.

SHEAR LEGS

The SHEAR LEGS is formed by crossing two timbers, poles, planks, pipes, or steel bars and lashing or bolting them together near the top. A sling is suspended from the lashed intersection and is used as a means of supporting the load tackle system. (See fig. 6-9.) In addition to the name *shear legs,* this rig is often referred to simply as a shears. (It has also been called an A-frame.)

The shear legs is used to lift heavy machinery and other bulky objects. It may also be used as end supports of a cableway and highline. A major reason for using the shears in fieldwork is that it can be quickly assembled and erected.

A shears requires only two guy lines and can be used for working at a forward angle. The forward guy does not have much strain imposed on it during hoisting. This guy is used primarily as an aid in adjusting the drift of the shears and in keeping the top of the rig steady when a load is being hoisted or placed. The after guy is an important part of the shears' rigging, as it is under considerable strain when hoisting. It should be designed for a strength equal to one half of the load to be lifted. The same principles for thrust on the spars apply; that is, the thrust increases drastically as the shear legs go off the perpendicular.

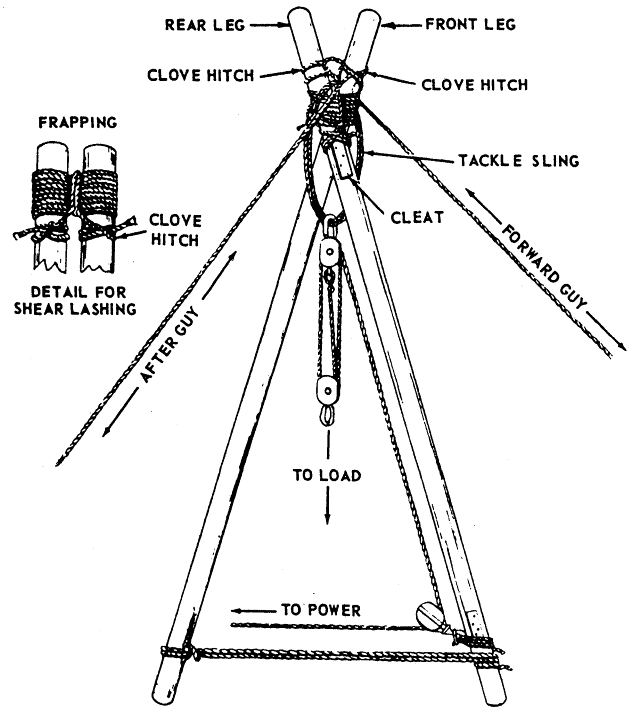


Figure 6-9.—Shear legs.

Rigging

In rigging the shears, place your two spars or poles on the ground parallel to each other with their butt ends even. Next, put a large block of wood under the tops of the legs just below the point of lashing, and place a small block of wood between the tops at the same point to facilitate handling of the lashing. Now, separate the poles a distance equal to about one third of the diameter of one pole.

For lashing material, use 18- or 21-thread small stuff. In applying the lashing, first make a clove hitch around one of the legs. Then, take eight or nine turns around both legs above the hitch, working towards the top of the legs. Remember to wrap the turns tightly so that the finished lashing will be smooth and free of kinks. To apply the frapping (tight lashings), make two or three turns around the lashing between the legs; then, with a clove hitch, secure the end of the line to the other leg just below the lashing (fig. 6-9).

Now, cross the legs of the shears at the tip and separate the butt ends of the two legs so that the spread between them is equal to one half of the height of the shears. Dig shallow holes about 1 foot (30 centimeters) deep at the butt end of each leg. The butts of the legs should be placed in these holes in erecting the shears. Placing the legs in the holes will keep them from kicking out in operations where the shears is at an angle other than vertical.

The next step is to form the sling for the hoisting falls. To do this, take a short length of line, pass it a sufficient number of times over the cross at the top of the shear, and tie the ends together.

Now, reeve a set of blocks and place the hook of the upper block through the sling; then secure the hook by mousing. Fasten a snatch block to the lower part of one of the legs, as shown in figure 6-9.

If you need to move the load horizontally by moving the head of the shears, rig a tackle in the after guy near its anchorage.

The guys—one forward guy and one after guy—are secured next to the top of the shears. Secure the forward guy to the rear leg and the after guy to the front leg, using a clove hitch in both instances. (See fig. 6-9.)

Erecting

Several crew members are needed for safe, efficient erection of the shears, the number being determined largely by the size of the rig. To help ensure good results, the erection crew should lift the top of the frame and walk it up by hand until the after guy tackle system takes over the load. When this point is reached, complete the raising of the shears into final position by hauling in on the tackle.

Remember to secure the forward guy to its anchorage before raising the legs, and maintain a slight tension on the line to control the movement. Also, after the shears has been raised, lash the butt ends with chain, line, or boards to keep them from spreading when a load is applied.

TRIPOD

A tripod consists of three legs of equal length lashed together at the top. (See fig. 6-10.) The fact that the tripod can be used only where hoisting is vertical places it at a distinct disadvantage in comparison with other hoisting devices. Its use will be limited primarily to jobs that involve hoisting over wells, mine shafts, or other excavations. A major advantage of the tripod is its great stability. In addition, it requires no guys or anchorages, and its load capacity is approximately 1 1/2 times greater than for shears made of the same size timbers.

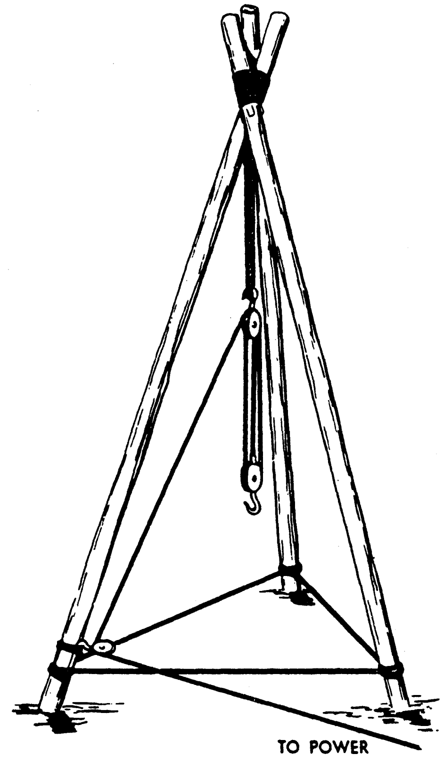


Figure 6-10.—Tripod.

The legs of a tripod generally are made of timber poles or pipes. Materials used for lashing include fiber line, wire rope, and chain. Metal rings joined with short chain sections are also available for insertion over the top of the tripod legs.

Rigging

The strength of a tripod depends largely on the strength of the material used for lashing as well as the amount of lashing used. The following procedure for lashing applies to line 3 inches (75 millimeters) in circumference or smaller. For extra heavy loads, use more turns than specified in the procedure given here; for light loads, use fewer turns than specified here.

As the first step of the procedure, take three spars of equal length and place a mark near the top of each to indicate the center of the lashing. Now, lay two of the spars parallel, with their TOPS resting on a skid (or block). Place the third spar between the two with the BUTT end resting on a skid. Position the spars so that the lashing marks on all three are in line. Leave an interval between the spars equal to about one half of the diameter of the spars. This will keep the lashing from being drawn too tight when the tripod is erected.

With the 3-inch (75-millimeter) line, make a clove hitch around one of the outside spars; put it about 4 inches (10 centimeters) above the lashing mark. Then make eight or nine turns with the line around all three spars. (See view A, fig. 6-11.) In making the turns, remember to maintain the proper amount of space between the spars.

Now, make one or two close frapping turns around the lashing between each pair of spars. Do not draw the turns too tight. Finally, secure the end of the line with a clove hitch on the center spar just above the lashing, as shown in view A, figure 6-11.

There is another method of lashing a tripod that you may find preferable to the method just given. It may be used in lashing slender poles up to 20 feet (6 meters) in length, or when some means other than hand power is available for erection.

First, place the three spars parallel to each other, leaving an interval between them slightly greater than twice the diameter of the line to be used. Rest the tip of each pole on a skid so that the end projects about 2 feet (60 centimeters) over the skid. Then, line up the butts of the three spars, as shown in view B, figure 6-11.

Next, make a clove hitch on one outside leg at the bottom of the position the lashing will occupy, which is about 2 feet (60 centimeters) from the end. Now, proceed to weave the line over the middle leg, under and around the other outside leg, under the middle leg, over and around the first leg, and so forth, until completing about eight or nine turns. Finish the lashing by forming a clove hitch on the other outside leg, as shown in view B, figure 6-11.

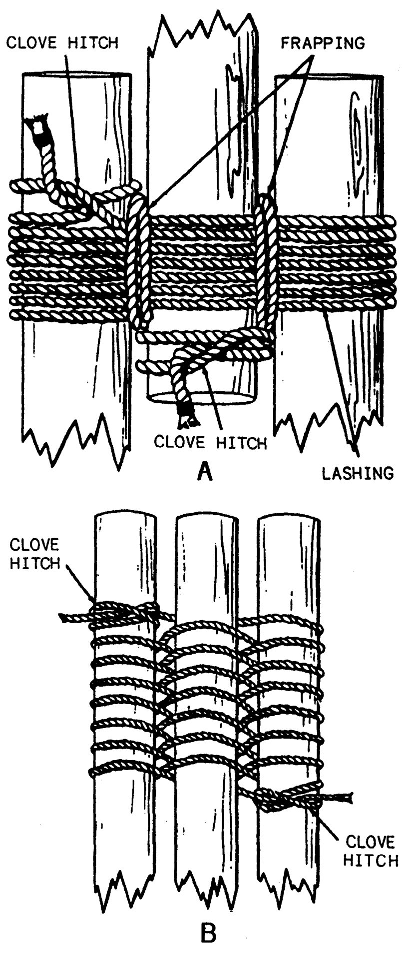


Figure 6-11.—Lashing for a tripod.

Erecting

In the final position of an erected tripod, it is important that the legs be spread an equal distance apart. The spread between legs must be not more than two thirds, nor less than one half, the length of a leg. Small tripods, or those lashed according to the first procedure given in the preceding section, may be raised by hand. Here are the main steps that make up the hand-erection procedure.

Start by raising the top ends of the three legs about 4 feet (1.2 meters), keeping the butt ends of the legs on the ground. Now, cross the tops of the two outer legs, and position the top of the third or center leg so that it rests on top of the cross.

A sling for the hoisting tackle can be attached readily by first passing the sling over the center leg, and then around the two outer legs at the cross. Place the hook of the upper block of the tackle on the sling, and secure the hook by mousing.

The raising operation can now be completed. To raise an ordinary tripod, a crew of about eight members may be required. As the tripod is being lifted, spread the legs so that when it is in the upright position, the legs will be spread the proper distance apart. After getting the tripod in its final position, lash the legs near the bottom with line or chain to keep them from shifting. (See fig. 6-10.)

Where desirable, a leading block for the hauling part of the tackle may be lashed to one of the tripod legs, as shown in figure 6-10.

In erecting a large tripod, you may need a small gin pole to aid in raising the tripod into position. When you are called on to assist in the erection of a tripod lashed according to the first lashing procedure described in the preceding section, the first thing to do is to raise the tops of the legs far enough from the ground to permit spreading them apart. Use guys or tag lines to help hold the legs steady while they are being raised. Now, with the legs clear of the ground, cross the two outer legs and place the center leg so that it rests on top of the cross. Then, attach the sling for the hoisting tackle. Here, as with a small tripod, simply pass the sling over the center leg and then around the two outer legs at the cross.

BOOM DERRICK

The BOOM DERRICK consists of a mast with a boom attached, as shown in figure 6-12. It may be used to move weight in any direction. You will find the boom derrick useful for loading and unloading trucks and flatcars when the base of weight-lifting equipment cannot be set close to the objects to be lifted. It is also used to advantage on docks and piers for unloading boats and barges.

For medium loads, the boom may be rigged to swing independently of the mast, as shown in figure 6-12. For heavy loads, the boom may be set on a turnplate or turn wheel and it and the mast rigged to swing as a unit. On more permanent installations, it is good practice to rig the mast separately and to strap another pole or

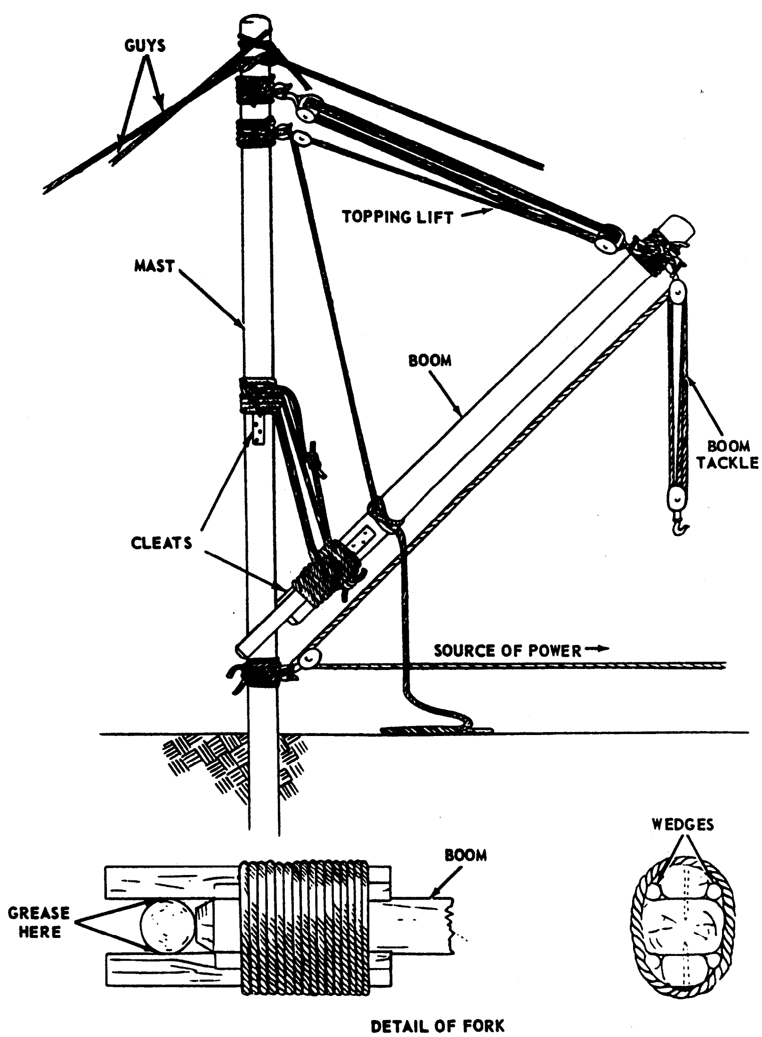


Figure 6-12.—Boom derrick.

mast to it. In such a case, one mast is fixed; the boom is rigged to the other mast, which is set on a turnplate. This provides rigid guying with a swing of more than 180° on the boom.

In case the proper size of line is not available, a set of tackle reeved with the same size line as that used in the hoisting tackle may be used as a guy by extending the tackle from the top of the derrick to the anchorage. See that the block attached to the derrick is lashed at that point where the other guys are tied and in the same manner.

Rigging

In fieldwork, you may be called on frequently to assist in rigging a boom derrick. For medium loads, follow the rigging procedure given below.

The first step is to rig a mast and lash the tackle on, which is used as the topping lift. If the hauling part of the topping lift tackle comes from the movable block, lash a fairlead block to the mast 2 or 3 feet (60 or 90 centimeters) below the topping lift lashing.

For your boom, select a pole, timber, steel pipe, beam, or laminated plank of the same diameter as the mast, but only about two thirds of its length. Attach two cleats to the butt end of the boom and lash them with small stuff to form a fork, as shown in figure 6-12. This fork is to keep the boom from getting away from the mast while a load is being moved from side to side. Use cleats long enough to extend from the butt end of the boom past the mast. About 4 feet (1.2 meters) above the point where the boom meets the mast, attach two cleats into the mast, and place a lashing of at least four turns of small stuff above the cleats, keeping two ends free.

Using a sling attached to the topping lift, raise the butt end of the boom as high as you want it. With the free ends from the lashing on the mast, make a sling to support the butt end of the boom.

Lash the movable block of the topping lift to the top end of the boom, and lash the fixed block of the boom tackle at the same point. The boom tackle is reeved so that the hauling part comes from the fixed block and passes through a fairlead block lashed at the base of the mast.

Erecting

Raise the boom into position after the above rigging is completed. When working with heavy loads, see that the base of the boom rests on the ground at the foot of the pole. When working with light loads, you may use a more horizontal position, thus providing a greater radius. In no case should the boom bear against any part of the upper two thirds of the mast.

To swing the boom, push directly on the load or pull the load with bridle lines or tag lines. The angle of the boom to the mast is adjusted by hauling on the hauling part of the topping lift. The load is raised or lowered by the hauling part of the boom tackle. A fairlead block (snatch block) is usually placed at the base of the mast. The hauling part of the boom tackle is led through this fairlead block to a hand- or power-operated winch for the actual hoisting of the load.

POLE DERRICK

Various types of light-hoisting equipment are sometimes used on construction projects. A typical example is the POLE DERRICK, also known as a DUTCHMAN, shown in figure 6-13. This device is often powered by means of a hand-operated or engine-driven winch. It can be set up readily in the field and moved about from job to job.

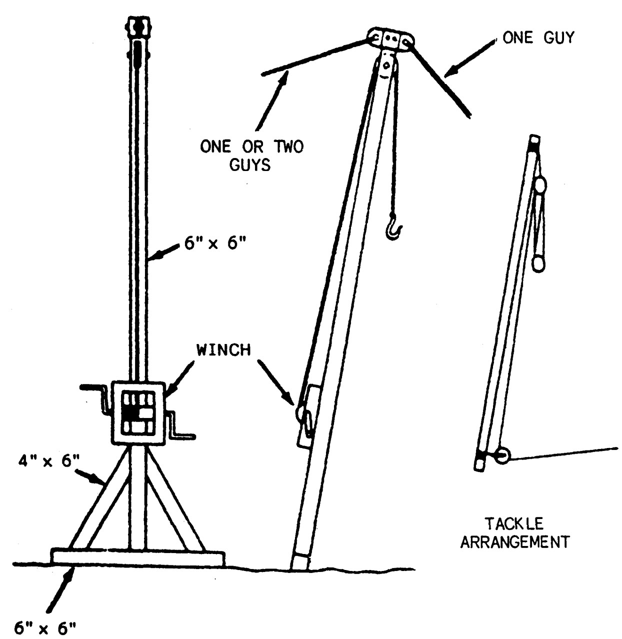


Figure 6-13.—Pole derrick, or Dutchman.

The pole derrick is essentially a gin pole constructed with a sill and with knee braces at the bottom. Also, guys usually are installed fore and aft. The pole derrick is suitable for lifting loads of 1 or 2 tons (0.9 or 1.8 metric tons). Since it is light in weight and has few guys, the device can be moved readily from place to place by a small crew.

OTHER HOISTING EQUIPMENT

The two sources of power you will use in hoisting are your work force and machine power. Of the two, machine power is more uniform. On a single vertical line, a crew member of average weight can pull with a force of 100 pounds (45 kilograms), while on a single horizontal line, the same crew member can pull with a force of only 60 pounds (27 kilograms). When you get several crew members on a single line, there is no way to measure the actual strength each crew member puts into the combined pull. When you have to use a lot of crew members, you will not be able to get enough personnel on a vertical line because of limited space. In this case, you should change the line to a horizontal pull by using a snatch block as a fairlead.

Machine power is much more predictable. In fact, all cranes have lift tables that show you their lifting capacities on the basis of a single-line pull. The power from winches and other hoists is also figured on a single-line pull.

As you already know, you can change your advantage by reeving different types of purchases. Always make the mechanical advantage fit your source of power. With some purchases, you have the extra feature of being able to increase mechanical advantage without increasing friction loss. A good example of this is the luff upon luff, which has twice the mechanical advantage of a threefold purchase, while the friction loss of 60 percent is the same with both. Because the friction loss remains the same on a luff upon luff, the use of it saves wear and tear on equipment.

CHAIN HOISTS

Chain hoists provide a convenient means for hoisting heavy objects. When a chain is used, the load can remain stationary without requiring attention. The slow lifting travel of a chain hoist is also advantageous in that it permits small movements, accurate adjustments of height, and cautious handling of loads.

Chain hoists differ widely in their mechanical advantage, depending upon their rated capacity. The mechanical advantage may vary from 5 to 250; that is, the ratio 5:1 to 250:1. Two types of chain hoists generally used for vertical hoisting operations are the spur gear hoist and the differential chain hoist.

The SPUR GEAR HOIST (fig. 6-14) is best for ordinary operations that require frequent use of a hoist and that have a minimum number of crew members available to operate it. The spur gear hoist is about 85-percent efficient. In other words, about 85 percent of the energy exerted by the operator is converted into useful work for lifting the load. The remaining 15 percent of the energy is spent in overcoming friction in the gears, bearings, chains, and so on.

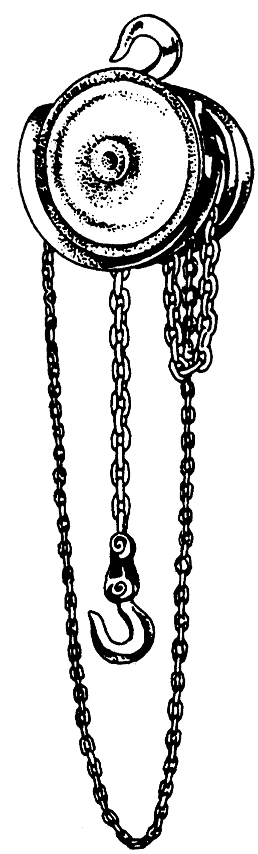


Figure 6-14.—Spur gear hoist.

The DIFFERENTIAL CHAIN HOIST (fig. 6-15) is suitable for light loads and in situations in which only occasional use of the hoist is involved. This hoist is only about 35-percent efficient.

A ratchet-handle pull hoist, commonly called a COME-ALONG, can be obtained and will prove beneficial for making short, horizontal pulls on heavy objects. A typical come-along, having a rated capacity of 1 1/2 tons, is shown in figure 6-16. You will find the come-along to be one of the most useful hoisting devices available. The chain will not foul up because it is flexible and cannot kink. The chain is kept in place in the sheave by a hardened steel-load chain guide.

The load capacity of a chain hoist usually is stamped on the shell of the upper block. The rated load capacity of hoists runs from 1/2 ton (0.45 metric tons) upward to 40 tons (36 metric tons).

The lower hook is usually the weakest part in the assembly of a chain hoist. This is intended as a safety measure so that the hook will start to spread open if overloaded. Spreading in a hook is a signal to the operator, warning that the chain hoist is nearing the overload point. Thus, close observance on the part of the operator is necessary to detect any sign of overloading in time to prevent damage to the chain hoist. Under ordinary circumstances, pull exerted on a chain hoist by one or two crew members in NOT enough to overload the hoist.

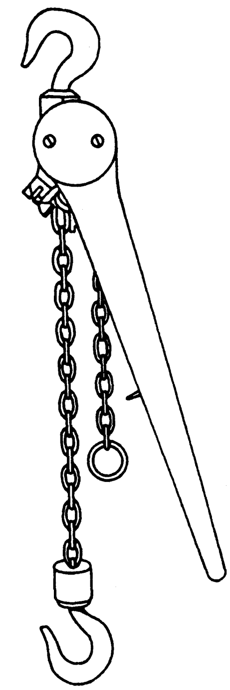


Figure 6-16.—Come-along.

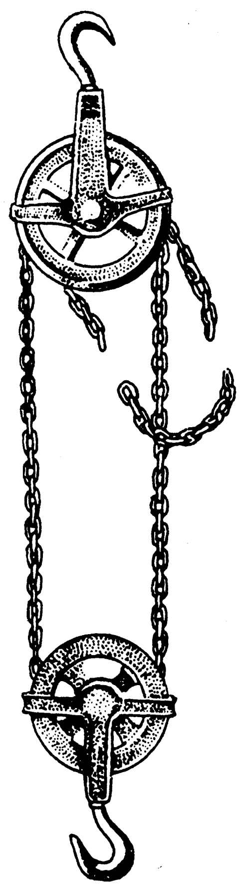


Figure 6-15.—Differential chain hoist.

Frequent inspection of chain hoists is necessary to ensure safe operation. A hook that shows signs of spreading or excessive wear should be replaced. If links in the chain are distorted, the chain hoist has probably been overloaded. In such a case, see that the chain hoist is condemned and removed from service immediately.

WINCHES

Winches are frequently used as a source of power for operating hoisting rigs, particularly gin poles, heavy-duty derricks, and light-hoisting equipment, such as pole derricks. A WINCH, generally speaking, is a device having one or more drums on which fiber line or wire rope is wound. Winches are used for hoisting or hauling of materials or objects. Both hand-operated and engine-driven winches of various types are available.

A single-drum, hand-operated winch similar to the one shown in figure 6-17 is suitable for lifting light loads. Single-drum hand winches are available in various capacities, including capacities of 2, 5, 6, and 15 tons (1.8, 4.5, 5.4, 12.5 metric tons).

Hand-operated winches are generally mounted near the foot of the rig, where they can be operated efficiently. Notice the location of the winch on the pole derrick shown in figure 6-13.

In hoisting and moving heavy objects in the field, engine-driven winches may be used with tackle. Vehicular-mounted winches are also widely used (fig. 6-18). Sources of power for power-driven winches include diesel, gasoline, compressed air, or steam engines as well as electric motors. When vehicular-mounted winches are used, the vehicle should be placed so that the operator can keep a close watch over the load during hoisting.

When setting up a power-driven winch to operate hoisting equipment, make sure you give careful consideration to these two factors: (1) the angle with the ground that the hoisting line makes at the drum of the hoist and (2) the fleet angle of the hoisting line winding on the drum.

In considering the ground angle, remember that if the hoisting line leaves the drum at an angle upward from the ground, the resulting pull on the winch will tend to lift it clear of the ground. In this case, a leading block should be placed in the system at some distance from the drum to change the direction of the hoisting line to a horizontal or downward pull. The hoisting line has to be overwound or underwound on the drum, as may be necessary, to prevent a reverse bend.

As for the fleet angle, bear in mind that the distance from the drum to the first sheave of the system is the controlling factor. Place the drum of the winch so that a line from the last block passing through the center of the drum is at right angles to the axis of the drum. The angle between this line and the hoisting line as it winds on the drum is referred to as the FLEET ANGLE.

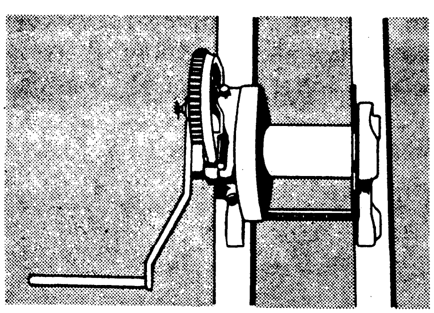


Figure 6-17.—Single-drum hand winch.

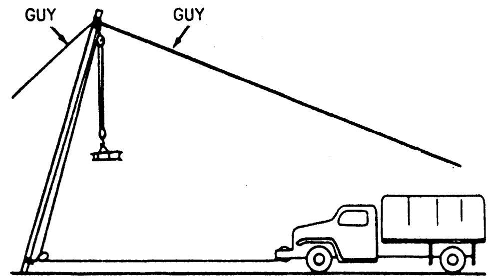


Figure 6-18.—Using a vehicular winch for hoisting.

As the hoisting line is wound in on the drum, it moves from one flange to the other, causing the fleet angle to change during the hoisting process. See that the fleet angle does NOT exceed 2°; and, where possible, keep it below this. A 1 1/2° maximum angle is satisfactory and will be obtained if the distance from the drum to the first sheave is 40 inches (100 centimeters) for each inch (2.5 centimeters) from the center of the drum to the flange. The wider the drum of the hoist, the greater the lead distance has to be when the winch is placed.

Most winches, even those made by the same manufacturer, differ from each other in their operation. If you are not familiar with the operation of a winch to be used on a job, study the operating procedure described in the manufacturer's manual beforehand. The fundamentals of winch operation must be understood to ensure safe, efficient handling of materials. The use of hand signals in giving directions to operators of winches is especially important to the safety of both the crew member and the material being hoisted.

CRANES

The crane is one of the most useful pieces of construction equipment. It is also one of the most versatile. For instance, by rigging the crane chassis with a boom and lifting hook, you have an excellent device for lifting and moving heavy materials, machinery, and other objects.

(See fig. 6-19.) The capacity of the crane for lifting depends on the boom length and angle. The capacity will be noted inside the cab of the crane, and this capacity should NOT be exceeded. You will not be required to operate the crane; that is the job of the Equipment Operator. But there are other important jobs, such as that of hook-on man or signalman, and you have to be able to handle either of these.

FIBER LINE

Fiber line is made from either natural or synthetic fiber. Natural fibers, which come from plants, include manila, sisal, and hemp. The synthetic fibers include nylon, polyester, and polypropylene.

SYNTHETIC-FIBER ROPES

Synthetic-fiber ropes, such as nylon and polyester, have rapidly gained wide use by the Navy. They are lighter in weight, more flexible, less bulky, and easier to handle and store than manila lines are. They are also highly resistant to mildew, rot, and fungus. Synthetic ropes are stronger than natural-fiber rope. For example, nylon is about three times stronger than manila. When nylon line is wet or frozen, the loss of strength is relatively small. Nylon rope will hold a load even though several strands may be frayed. Ordinarily, the line can be made reusable by cutting away the chafed or frayed section and splicing the good line together.

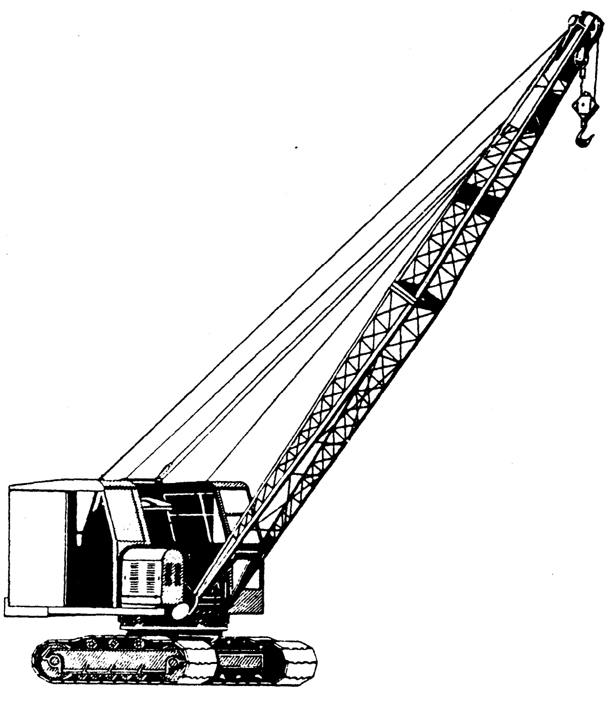


Figure 6-19.—Crane rigged with boom and lifting hook.

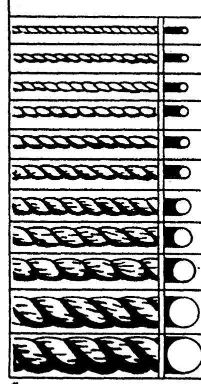
SIZE DESIGNATION

Line that is 1 3/4 inches or less in circumference is called SMALL STUFF, and the size is usually designated by the number of THREADS (or yarns) that make up each strand. You may use from 6- to 24-thread strands, but the most commonly used are 9- to 21-thread strands (fig. 6-20). You may hear some small stuff designated by name without reference to size. One such type is MARLINE, a tarred, two-strand, left-laid hemp. Marline is the small stuff you will use most for seizings. When you need something stronger than marline, you will use a tarred, three-strand, left-laid hemp called HOUSELINE.

Line larger than 1 3/4 inches in circumference is generally designated as to size by its circumference in inches. A 6-inch manila line, for instance, would be constructed of manila fibers and measure 6 inches in circumference. Line is available in sizes ranging up to 16 inches in circumference, but 12 inches is about the largest carried in stock. Anything larger is used only on special jobs. (See fig. 6-20.)

MANILA LINE

SOME COMMONLY USED SIZES	* CIRCUMFERENCE INCHES	* CIRCUMFERENCE MILLIMETERS	THREAD
	3/4	19.05	6
	1	25.40	9
	1 1/8	28.58	12
	1 1/4	31.76	15
	1 1/2	38.10	21
	1 3/4	44.45	24
	2	50.80	
	3	76.20	
	4	101.6	
	5	127.0	
	6	152.4	



* SIZE IS DESIGNATED BY THE CIRCUMFERENCE

Figure 6-20.—Some commonly used sizes of manila line.

If you should be tasked to order line, you may find that in the catalogs it is designated and ordered by diameter. The catalog may also use the term *rope* (rather than line).

ROPE YARNS for temporary seizings, whippings, and lashings are pulled from large strands of old line that has outlived its usefulness. Pull your yarn from the middle, away from the ends, or it will get fouled.

STRENGTH OF FIBER LINE

Overloading a line poses a serious threat to the safety of personnel, not to mention the heavy losses likely to result through damage to material. To avoid overloading, you must know the strength of the line with which you are working. This involves three factors: breaking strength, safe working load, and safety factor.

BREAKING STRENGTH refers to the tension at which the line will part when a load is applied. Breaking strength has been determined through tests made by rope manufacturers, and tables have been set up to provide this information. In the absence of manufacturers' tables, a rule of thumb for finding the breaking strength of manila line is as follows:

$$C^2 \times 900 = BS$$

In the rule, C equals the circumference in inches, and BS equals the breaking strength in pounds. To find BS, square the circumference and then multiply the figure obtained by 900. With a 3-inch line, for example, you will get a BS of 8,100 pounds, figuring as follows:

$$3 \times 3 \times 900 = 8{,}100 \text{ lb}$$

The breaking strength of manila line is higher than that of sisal line. This is caused by the difference in strength of the two fibers. The fiber from which a particular line is constructed has a definite bearing on its breaking strength.

The breaking strength of nylon line is almost three times that of manila line of the same size. The best rule of thumb for the breaking strength of nylon is as follows:

$$BS = C^2 \times 2400$$

The symbols in the rule are the same as those for fiber line.

For 2 1/2-inch nylon line,

$$BS = 2.5 \times 2.5 \times 2{,}400 = 15{,}000 \text{ lb}$$

SAFE WORKING LOAD

Briefly defined, the "safe working load" (SWL) of a line is the load that can be applied without causing any kind of damage to the line. Note that the safe working load is considerably less than the breaking strength. A wide margin of difference between breaking strength and safe working load is necessary to allow for such factors as additional strain imposed on the line by jerky movements in hoisting or bending over sheaves in a pulley block.

You may not always have a chart available to tell you the safe working load for a particular size line-so what do you do then? Fortunately, there is a rule of thumb that will adequately serve your needs on such an occasion.

$$SWL = C^2 \times 150$$

Where SWL equals the safe working load in pounds and C equals the circumference of the line in inches, you simply take the circumference of the line, square it, and then multiply by 150. For a 3-inch line, here is how the rule works.

$$3 \times 3 \times 150 = 1{,}350 \text{ lb}$$

Thus, the safe working load of a 3-inch line is equal to 1,350 pounds.

If the line is in good shape, add 30 percent to the SWL determined by means of the rule; or if it is in bad shape, subtract 30 percent from the SWL. In the example given above for the 3-inch line, adding 30 percent to the 1,350 lb would give you a safe working load of 1,755 lb. On the other hand, subtracting 30 percent from the 1,350 lb would leave you a safe working load of 945 lb.

Remember that the strength of a line decreases with age, use, and exposure to excessive heat, boiling water, or sharp bends. Especially with used line, these and other factors affecting strength should be given careful consideration, and proper adjustment should be made in the breaking strength and safe working load capacity of the line. Manufacturers of line provide tables to show the breaking strength and safe working load capacity of line. You will find such tables useful in your work. You must remember, however, that the values given in manufacturers' tables apply only to new line being used under favorable conditions. For that reason, you must progressively reduce the values given in manufacturers' tables as the line ages or deteriorates with use.

The SAFETY FACTOR of a line is the ratio between the breaking strength and the safe working load. Usually, a safety factor of 4 is acceptable, but this is not always the case. In other words, the safety factor will vary, depending on such things as the condition of the line and circumstances under which it is to be used. While the safety factor should NEVER be less than 3, it often should be well above 4 (possibly as high as 8 or 10). For best, average, or unfavorable conditions, the safety factor indicated below may often be suitable.

BEST conditions (new line): 4

AVERAGE conditions (line used, but in good condition): 6

UNFAVORABLE conditions (frequently used line, such as running rigging): 8

WIRE ROPE

During the course of a project, SEABEEs often need to hoist or move heavy objects. Wire rope is used for heavy-duty work. The characteristics, construction, and usage of many types of wire rope are discussed in the following paragraphs. We will also discuss the safe working load, use of attachments and fittings, and procedures for the care and handling of wire rope.

CONSTRUCTION

Wire rope consists of three parts: wires, strands, and core (fig. 6-21). In the manufacture of rope, a number of WIRES are laid together to form the STRAND. Then a number of STRANDS are laid together around a CORE to form the ROPE.

The basic unit of wire rope construction is the individual wire, which may be made of steel, iron, or other metal in various sizes. The number of wires to a strand will vary, depending on the purpose for which the rope is intended. Wire rope is designated by the number of strands per rope and the number of wires per strand. Thus, a 1/2-inch, 6 by 19 wire rope will have 6 strands with 19 wires per strand; but it will have the same outside diameter as a 1/2-inch, 6 by 37 wire rope, which will have 6 strands with 37 wires of much smaller size per strand.

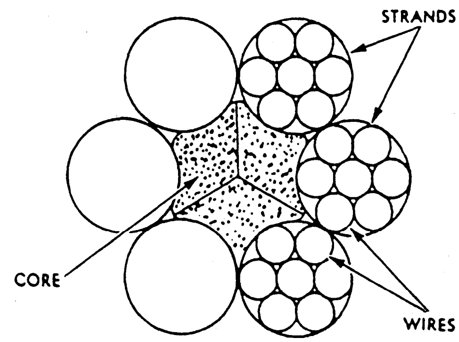


Figure 6-21.—Parts of a wire rope.

Wire rope that is made up of a large number of small wires is flexible. The small wires are, however, easily broken, so the wire rope does not resist external abrasion. Wire rope that is made up of a smaller number of larger wires is more resistant to external abrasion but is less flexible.

The CORE-the element around which the strands are laid to form the rope-may be a hard fiber (such as manila, hemp, plastic, paper, asbestos, or sisal), a wire strand, or an independent wire rope. Each type of core serves the same basic purpose—to support the strands laid around it.

A FIBER CORE offers the advantage of increased flexibility. Also, it serves as a cushion to reduce the effects of sudden strain and acts as a reservoir for the oil to lubricate the wires and strands to reduce friction between them. Wire rope with a fiber core is used in places where flexibility of the rope is important.

A WIRE STRAND CORE not only resists heat better than a fiber core, but it also adds about 15 percent to the strength of the rope. On the other hand, the wire strand makes the rope less flexible than a fiber core would.

An INDEPENDENT WIRE ROPE CORE is a separate wire rope over which the main strands of the rope are laid. It usually consists of six 7-wire strands laid around either a fiber core or a wire strand core. This core strengthens the rope more, provides support against crushing, and supplies maximum resistance to heat.

Wire rope may be made by either of two methods. If the strands or wires are shaped to conform to the curvature of the finished rope before laying up, the rope is termed *preformed.*

If they are not shaped before fabrication, the rope is termed *nonpreformed.* When cut, preformed wire rope tends not to unlay, and it is more flexible than nonpreformed wire rope. With nonpreformed wire rope, twisting produces a stress in the wires; and, when it is cut or broken, the stress causes the strands to unlay. In nonpreformed wire, unlaying is rapid and almost instantaneous, which could cause serious injury to someone not familiar with it.

The main types of wire rope used by the Navy have 6, 7, 12, 19, 24, or 37 wires in each strand. Usually, the rope has six strands laid around a fiber or steel center.

Two common types of wire rope, 6 by 19 and 6 by 37 rope, are shown in figure 6-22. The 6 by 19 type of rope, having 6 strands with 19 wires in each strand, is commonly used for rough hoisting and skidding work where abrasion is likely to occur. The 6 by 37 wire rope, having 6 strands with 37 wires in each strand, is the most flexible of the standard six-strand ropes. For that reason, it is particularly suitable when small sheaves and drums are to be used, such as on cranes and similar machinery.

GRADES OF WIRE ROPE

Wire rope is made in a number of different grades, three of which are mild plow steel, plow steel, and improved plow steel.

MILD PLOW STEEL rope is tough and pliable. It can stand up under repeated strain and stress, and it has a tensile strength of 200,000 to 220,000 pounds per square inch (psi).

PLOW STEEL wire rope is unusually tough and strong. This steel has a tensile strength (resistance to lengthwise stress) of 220,000 to 240,000 psi. This rope is suitable for hauling, hoisting, and logging.

IMPROVED PLOW STEEL rope is one of the best grades of rope available, and most, if not all, of the wire rope in your work will probably be made of this material. It is stronger, tougher, and more resistant to wear than either plow steel or mild plow steel. Each square inch of improved plow steel can stand a strain of 240,000 to 260,000 psi.

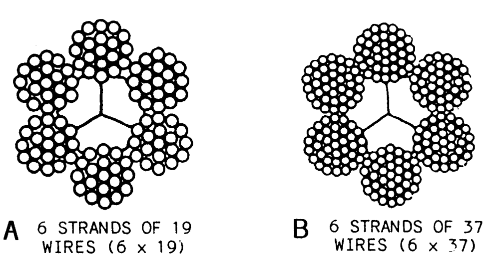


Figure 6-22.—Two common types of wire rope.

MEASURING WIRE ROPE

The size of wire rope is designated by its diameter. The true diameter of a wire rope is considered as being the diameter of the circle that will just enclose all of its strands. Both the correct and incorrect methods of measuring wire rope are shown in figure 6-23. Note, in particular, that the CORRECT WAY is to measure from the top of one strand to the top of the strand directly opposite it. The wrong way is to measure across two strands side by side. Use calipers to take the measurement; if calipers are not available, an adjustable wrench will do.

To ensure an accurate measurement of the diameter of a wire rope, always measure the rope at three places, at least 5 feet apart. Use the average of the three measurements as the diameter of the rope.

SAFE WORKING LOAD

The term *safe working load* (SWL), as used in reference to wire rope, means the load that can be applied and still obtain the most efficient service and also prolong the life of the rope. Most manufacturers provide tables that show the safe working load for their rope under various conditions. In the absence of these tables, you have to apply a thumb-rule formula to obtain the SWL. There are rules of thumb that may be used

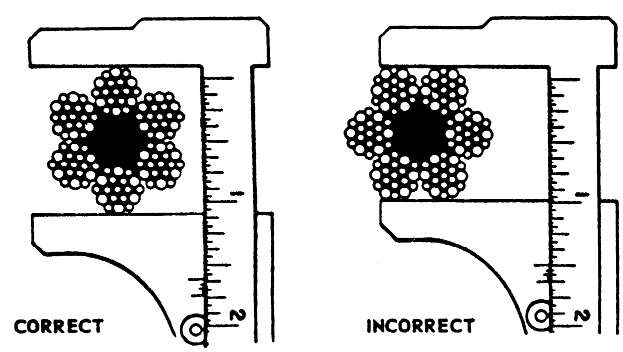


Figure 6-23.—Correct and incorrect methods of measuring wire rope.

to compute the strength of wire rope. The one recommended by the Naval Facilities Engineering Command (NAVFAC) is as follows:

$$\text{SWL (in tons)} = D^2 \times 4$$

This particular formula provides an ample safety margin to account for such variables as the number, size, and location of sheaves and drums on which the rope runs, and such dynamic stresses as the speed of operation and the acceleration and deceleration of the load, all of which can affect the endurance and breaking strength of the rope.

In the above formula, D represents the diameter of the rope in inches. Suppose you want to find the SWL of a 2-inch rope. Using the formula above, your figures would be as follows:

$$\text{SWL} = (2)^2 \times 4$$

$$\text{SWL} = 4 \times 4 = 16$$

The answer is 16, meaning that the rope has an SWL of 16 tons.

It is important to remember that any formula for determining SWL is only a rule of thumb. In computing the SWL of old rope, worn rope, or rope that is otherwise in poor condition, you should reduce the SWL as much as 50 percent, depending on the condition of the rope.

The manufacturer's data concerning the breaking strength (BS) of wire rope should be used if available. But if you do not have that information, one rule of thumb recommended is as follows:

$$\text{BS} = C^2 \times 8{,}000 \text{ lb}$$

As you know, wire rope is measured by the diameter (D). To obtain the circumference (C) required in the formula, multiply D by pi (π), which is approximately 3.1416. Thus, the formula to find the circumference is $C = D\pi$.